

A DIAGRAMMATIC CATEGORIFICATION OF THE Q-SCHUR ALGEBRA

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ABSTRACT. In this paper we categorify the q -Schur algebra $S_q(n, d)$ as a quotient of Khovanov and Lauda's diagrammatic 2-category $\mathcal{U}(\mathfrak{sl}_n)$ [16]. We also show that our 2-category contains Soergel's [33] monoidal category of bimodules of type A , which categorifies the Hecke algebra $H_q(d)$, as a full sub-2-category if $d \leq n$. For the latter result we use Elias and Khovanov's diagrammatic presentation of Soergel's monoidal category of type A [8].

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1. INTRODUCTION

There is a well-known relation, called *Schur-Weyl duality* or *reciprocity*, between the polynomial representations of homogeneous degree d of the general linear group $\mathrm{GL}(n, \mathbb{Q})$ and the finite-dimensional representations of the symmetric group on d letters S_d . Recall that all irreducible polynomial representations of $\mathrm{GL}(n, \mathbb{Q})$ of homogeneous degree d occur in the decomposition of $V^{\otimes d}$, where $V = \mathbb{Q}^n$ is the natural representation of $\mathrm{GL}(n, \mathbb{Q})$. Instead of the $\mathrm{GL}(n, \mathbb{Q})$ -action, we can consider the $\mathrm{U}(\mathfrak{gl}_n)$ -action, without loss of generality. A key observation for Schur-Weyl duality is that the permutation action of S_d on $V^{\otimes d}$ commutes with the action of $\mathrm{U}(\mathfrak{gl}_n)$. Furthermore, we have

$$\mathbb{Q}[S_d] \cong \mathrm{End}_{\mathrm{U}(\mathfrak{gl}_n)}(V^{\otimes d})$$

if $n \geq d$.

By definition, the *Schur algebra* is the other centralizer algebra

$$S(n, d) := \mathrm{End}_{S_d}(V^{\otimes d}).$$

It is well known that both $\mathrm{U}(\mathfrak{sl}_n)$ and $\mathrm{U}(\mathfrak{gl}_n)$ map surjectively onto $S(n, d)$, for any $d > 0$. Therefore we can also define $S(n, d)$ as the image of the map

$$\mathrm{U}(\mathfrak{gl}_n) \rightarrow \mathrm{End}_{\mathbb{Q}}(V^{\otimes d}),$$

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The Q-Schur Algebra Stephen Donkin, 1998-12-10 This book focuses on the representation theory of q Schur algebras and connections with the representation theory of Hecke algebras and quantum general linear groups. The aim is to present from a unified point of view quantum analogs of certain results known already in the classical case. The approach is largely homological based on Kempf's vanishing theorem for quantum groups and the quasi hereditary structure of the q Schur algebras. Beginning with an introductory chapter dealing with the relationship between the ordinary general linear groups and their quantum analogies the text goes on to discuss the Schur Functor and the 0 Schur algebra. The next chapter considers Steinberg's tensor product and infinitesimal theory. Later sections of the book discuss tilting modules, the Ringel dual of the q Schur algebra, Specht modules for Hecke algebras and the global dimension of the q Schur algebras. An appendix gives a self contained account of the theory of quasi hereditary algebras and their associated tilting modules. This volume will be primarily of interest to researchers in algebra and related topics in pure mathematics. *Schur Algebras and Representation Theory* Stuart Martin, 1993 The Schur algebra is an algebraic system providing a link between the representation theory of the symmetric and general linear groups both finite and infinite. In the text Dr Martin gives a full self contained account of this algebra and these links covering both the basic theory of Schur algebras and related areas. He discusses the usual representation theoretic topics such as constructions of irreducible modules, the blocks containing them, their modular characters and the problem of computing decomposition numbers; moreover deeper properties such as the quasi hereditariness of the Schur algebra are discussed. The opportunity is taken to give an account of quantum versions of Schur algebras and their relations with certain q deformations of the coordinate rings of the general linear group. The approach is combinatorial where possible making the presentation accessible to graduate students. This is the first comprehensive text in this important and active area of research; it will be of interest to all research workers in representation theory.

The Q-Schur Algebra Stephen Donkin, 2014-05-14 This book focuses on the representation theory of q Schur algebras and connections with the representation theory of Hecke algebras and quantum general linear groups. The aim is to present from a unified point of view quantum analogs of certain results known already in the classical case. The approach is largely homological based on Kempf's vanishing theorem for quantum groups and the quasi hereditary structure of the q Schur algebras. Beginning with an introductory chapter dealing with the relationship between the ordinary general linear groups and their quantum analogies the text goes on to discuss the Schur Functor and the 0 Schur algebra. The next chapter considers Steinberg's tensor product and infinitesimal theory. Later sections of the book discuss tilting modules, the Ringel dual of the q Schur algebra, Specht modules for Hecke algebras and the global dimension of the q Schur algebras. An appendix gives a self contained account of the theory of quasi hereditary algebras and their associated tilting modules. This volume will be primarily of interest to researchers in algebra and related topics in pure mathematics. The Q-Schur

Algebra S. Donkin, 1999 This book focuses on the representation theory of q Schur algebras **A Double Hall Algebra Approach to Affine Quantum Schur-Weyl Theory** Bangming Deng, Jie Du, Qiang Fu, 2012-12-06 The first book of its kind to present an algebraic approach to affine q Schur algebras and affine quantum Schur Weyl theory *The Q-Schur Algebra* S. Donkin, 1998 Iwahori-Hecke Algebras and Schur Algebras of the Symmetric Group Andrew Mathas, 1999 This volume presents a fully self contained introduction to the modular representation theory of the Iwahori Hecke algebras of the symmetric groups and of the q Schur algebras The study of these algebras was pioneered by Dipper and James in a series of landmark papers The primary goal of the book is to classify the blocks and the simple modules of both algebras The final chapter contains a survey of recent advances and open problems The main results are proved by showing that the Iwahori Hecke algebras and q Schur algebras are cellular algebras in the sense of Graham and Lehrer This is proved by exhibiting natural bases of both algebras which are indexed by pairs of standard and semistandard tableaux respectively Using the machinery of cellular algebras which is developed in chapter 2 this results in a clean and elegant classification of the irreducible representations of both algebras The block theory is approached by first proving an analogue of the Jantzen sum formula for the q Schur algebras This book is the first of its kind covering the topic It offers a substantially simplified treatment of the original proofs The book is a solid reference source for experts It will also serve as a good introduction to students and beginning researchers since each chapter contains exercises and there is an appendix containing a quick development of the representation theory of algebras A second appendix gives tables of decomposition numbers Borel Type Subalgebras of the Q-Schur Algebra Du. J., 1998 **Q-Schur Algebras, Asymptotic Forms and Quantum SL n** Jie Du, 1993* **Cells and Q-Schur Algebras** Jie Du, Brian Parshall, Leonard Scott, 1996 **Algorithmic Algebra and Number Theory** B. Heinrich Matzat, Gert-Martin Greuel, Gerhard Hiss, 2012-12-06 This book contains 22 lectures presented at the final conference of the German research program Schwerpunktprogramm Algorithmic Number Theory and Algebra 1991 1997 sponsored by the Deutsche Forschungsgemeinschaft The purpose of this research program and of the meeting was to bring together developers of computer algebra software and researchers using computational methods to gain insight into experimental problems and theoretical questions in algebra and number theory The book gives an overview on algorithmic methods and on results obtained during this period This includes survey articles on the main research projects within the program algorithmic number theory emphasizing class field theory constructive Galois theory computational aspects of modular forms and of Drinfeld modules computational algebraic geometry including real quantifier elimination and real algebraic geometry and invariant theory of finite groups computational aspects of presentations and representations of groups especially finite groups of Lie type and their Hecke algebras and of the isomorphism problem in group theory Some of the articles illustrate the current state of computer algebra systems and program packages developed with support by the research program such as KANT and LiDIA for algebraic number theory SINGULAR RED LOG and INVAR for commutative

algebra and invariant theory respectively and GAP SYSPHOS and CHEVIE for group theory and representation theory

Group Theory in China Zhexian Wan, Sheng-Ming Shi, 1996 Hsio Fu Tuan is a Chinese mathematician who has made important contributions to the theories of both finite groups and Lie groups He has also had a great influence on the development of algebra and particularly group theory in China The present volume consists of a collection of essays on various aspects of group theory written by some of his former students and colleagues in honour of his 80th birthday The papers contain the main general results as well as recent ones on certain topics within this discipline The chief editor Zhexian Wan is a leading algebraist in China

Finite Dimensional Algebras and Quantum Groups Bangming Deng, 2008 The interplay between finite dimensional algebras and Lie theory dates back many years In more recent times these interrelations have become even more strikingly apparent This text combines for the first time in book form the theories of finite dimensional algebras and quantum groups More precisely it investigates the Ringel Hall algebra realization for the positive part of a quantum enveloping algebra associated with a symmetrizable Cartan matrix and it looks closely at the Beilinson Lusztig MacPherson realization for the entire quantum $\mathfrak{gl}_n$ The book begins with the two realizations of generalized Cartan matrices namely the graph realization and the root datum realization From there it develops the representation theory of quivers with automorphisms and the theory of quantum enveloping algebras associated with Kac Moody Lie algebras These two independent theories eventually meet in Part 4 under the umbrella of Ringel Hall algebras Cartan matrices can also be used to define an important class of groups Coxeter groups and their associated Hecke algebras Hecke algebras associated with symmetric groups give rise to an interesting class of quasi hereditary algebras the quantum Schur algebras The structure of these finite dimensional algebras is used in Part 5 to build the entire quantum $\mathfrak{gl}_n$ through a completion process of a limit algebra the Beilinson Lusztig MacPherson algebra The book is suitable for advanced graduate students Each chapter concludes with a series of exercises ranging from the routine to sketches of proofs of recent results from the current literature Publisher's website

Representations of Finite Dimensional Algebras and Related Topics in Lie Theory and Geometry Vlastimil Dlab, Claus Michael Ringel, 2004 These proceedings are from the Tenth International Conference on Representations of Algebras and Related Topics ICRA X held at The Fields Institute In addition to the traditional instructional workshop preceding the conference there were also workshops on Commutative Algebra Algebraic Geometry and Representation Theory Finite Dimensional Algebras Algebraic Groups and Lie Theory and Quantum Groups and Hall Algebras These workshops reflect the latest developments and the increasing interest in areas that are closely related to the representation theory of finite dimensional associative algebras Although these workshops were organized separately their topics are strongly interrelated The workshop on Commutative Algebra Algebraic Geometry and Representation Theory surveyed various recently established connections such as those pertaining to the classification of vector bundles or Cohen Macaulay modules over Noetherian rings coherent sheaves on curves or ideals in Weyl algebras In

addition methods from algebraic geometry or commutative algebra relating to quiver representations and varieties of modules were presented The workshop on Finite Dimensional Algebras Algebraic Groups and Lie Theory surveyed developments in finite dimensional algebras and infinite dimensional Lie theory especially as the two areas interact and may have future interactions The workshop on Quantum Groups and Hall Algebras dealt with the different approaches of using the representation theory of quivers and species in order to construct quantum groups working either over finite fields or over the complex numbers In particular these proceedings contain a quite detailed outline of the use of perverse sheaves in order to obtain canonical bases The book is recommended for graduate students and researchers in algebra and geometry

Cyclotomic Q-Schur Algebras Richard Dipper, Gordon James, Andrew Mathas, 1997 *New Directions in Hopf Algebras* Susan Montgomery, Hans-Jurgen Schneider, 2002-05-06 Hopf algebras have important connections to quantum theory Lie algebras knot and braid theory operator algebras and other areas of physics and mathematics They have been intensely studied in the past in particular the solution of a number of conjectures of Kaplansky from the 1970s has led to progress on the classification of semisimple Hopf algebras and on the structure of pointed Hopf algebras Among the topics covered are results toward the classification of finite dimensional Hopf algebras semisimple and non semisimple as well as what is known about the extension theory of Hopf algebras Some papers consider Hopf versions of classical topics such as the Brauer group while others are closer to work in quantum groups The book also explores the connections and applications of Hopf algebras to other fields **Modular Representation Theory of Finite Groups** Michael J. Collins, Brian J. Parshall, Leonard L. Scott, 2011-07-11 This book is an outgrowth of a Research Symposium on the Modular Representation Theory of Finite Groups held at the University of Virginia in May 1998 The main themes of this symposium were representations of groups of Lie type in nondefining or cross characteristic and recent developments in block theory Series of lectures were given by M Geck A Kleshchev and R Rouquier and their brief was to present material at the leading edge of research but accessible to graduate students working in the field The first three articles are substantial expansions of their lectures and each provides a complete account of a significant area of the subject together with an extensive bibliography The remaining articles are based on some of the other lectures given at the symposium some again are full surveys of the topic covered while others are short but complete research articles The opportunity has been taken to produce a book of enduring value so that this is not a conference proceedings in the conventional sense Material has been updated so that this book through its own content and in its extensive bibliographies will serve as an invaluable resource for all those working in the area whether established researchers or graduate students who wish to gain a general knowledge of the subject starting from a single source

Quantum Groups and Lie Theory Andrew Pressley, 2002-01-17 Since its genesis in the early 1980s the subject of quantum groups has grown rapidly By the late 1990s most of the foundational issues had been resolved and many of the outstanding problems clearly formulated To take stock and to discuss the most fruitful directions for future research many of

the world's leading figures in this area met at the Durham Symposium on Quantum Groups in the summer of 1999 and this volume provides an excellent overview of the material presented there. It includes important surveys of both cyclotomic Hecke algebras and the dynamical Yang-Baxter equation. Plus contributions which treat the construction and classification of quantum groups or the associated solutions of the quantum Yang-Baxter equation. The representation theory of quantum groups is discussed as is the function algebra approach to quantum groups and there is a new look at the origins of quantum groups in the theory of integrable systems.

The Atlas of Finite Groups - Ten Years On Robert Curtis, 1998-06-11
 Proceedings containing twenty articles by leading experts in group theory and its applications

Representation Theory of Finite Groups and Finite-Dimensional Algebras Michler, Ringel, 2012-12-06
 From April 1 1984 until March 31 1991 the Deutsche Forschungsgemeinschaft has sponsored the project Representation Theory of Finite Groups and Finite Dimensional Algebras. The proposal for this project was submitted by B Huppert Mainz B Fischer Bielefeld G Michler Essen H Pahlings Aachen and C M Ringel Bielefeld in order to strengthen the interaction between the different research areas in representation theory. The Deutsche Forschungsgemeinschaft has given many research positions and fellowships for young algebraists enabling them to do research at their own universities or as visitors at well known research institutions in America Australia England and France. The whole project benefitted very much from an extensive exchange programme between German and American scientists sponsored by the Deutsche Forschungsgemeinschaft and by the National Science Foundation of the United States. This volume presents lectures given in a final conference and reports by members of the project. It is divided into two parts. The first part contains seven survey articles describing recent advances in different areas of representation theory. These articles do not only concentrate on the work done by the German research groups but also inform on major developments of the subject at all. The volume omits those topics already treated in book form. In particular it does not contain a survey on K.

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